L1CaloTrigger Algorithms

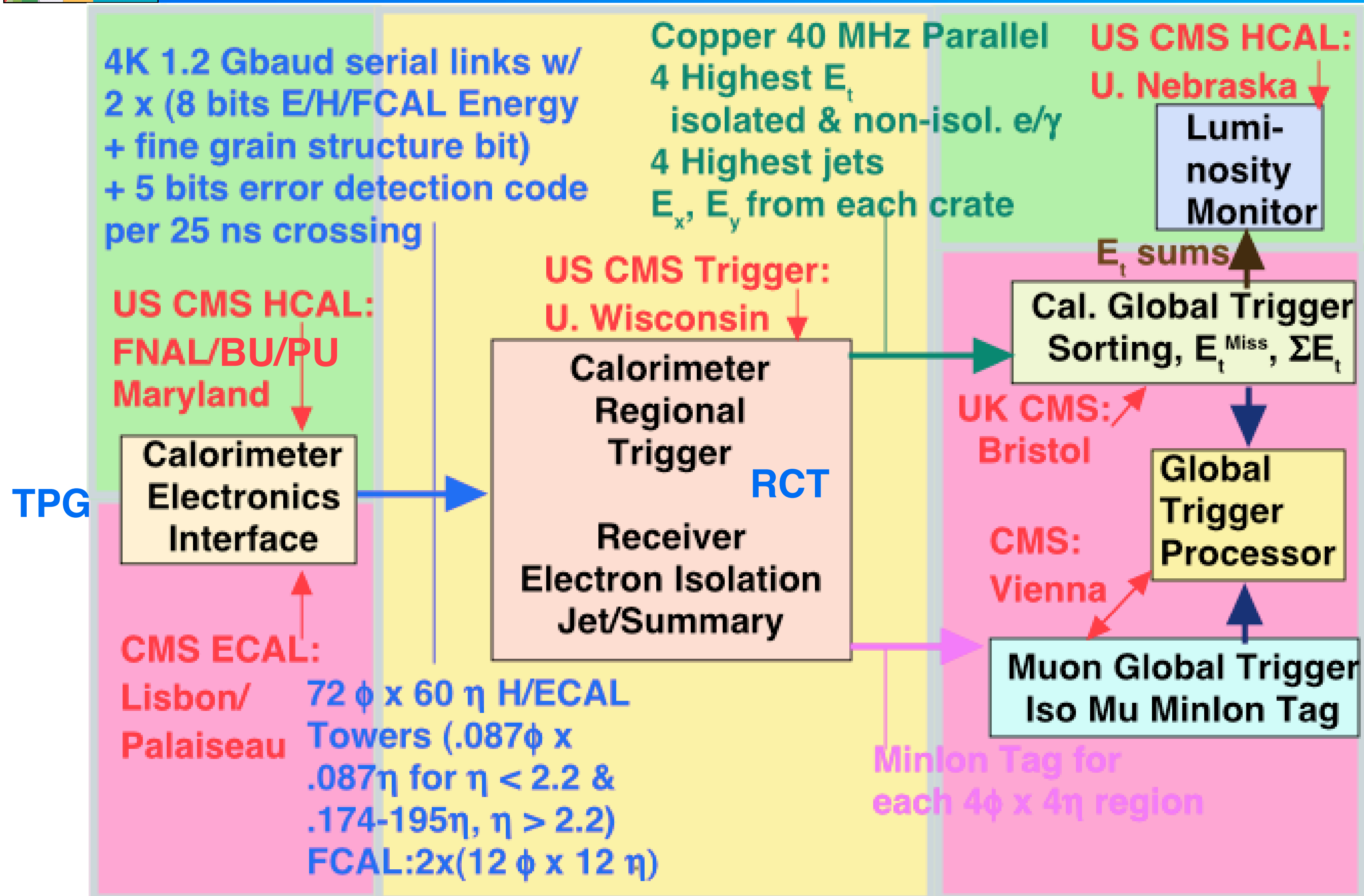
Sridhara Dasu

University of Wisconsin

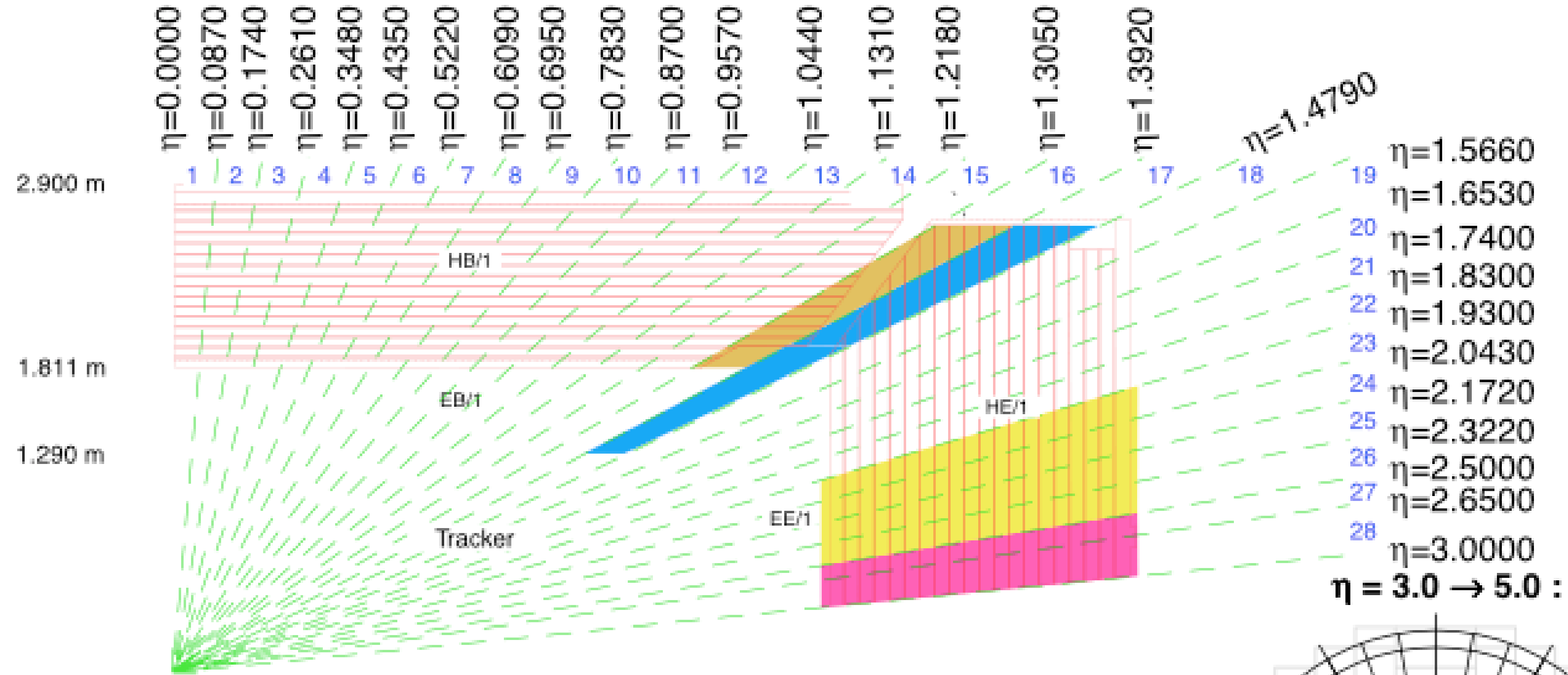
Algorithms: Details, Updates and Simulation

- 2×10^{33} cm^{-2} s^{-1} studies (CMS IN 2002/19)
    - Highlights
- Good jets and H_T
    - What will be implemented in GCT/GT
- Unexplored features - invitation to participate
    - Define LUTs etc. in RCT, GCT
    - Define GT algorithms

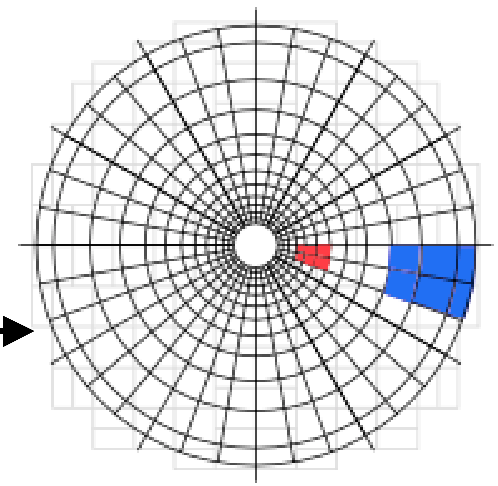
Overview


4K 1.2 Gbaud serial links w/
2 x (8 bits E/H/FCAL Energy
+ fine grain structure bit)
+ 5 bits error detection code
per 25 ns crossing
Copper 40 MHz Parallel
4 Highest E_t
isolated & non-isol. e/γ
4 Highest jets
E_x, E_y from each crate
US CMS HCAL:
U. Nebraska
Lumi-
nosity
Monitor
E_t sums
US CMS HCAL:
FNAL/BU/PU
Maryland
US CMS Trigger:
U. Wisconsin
Cal. Global Trigger
Sorting, E_t^{Miss}, ΣE_t
GCT
Calorimeter
Regional
Trigger
RCT
Receiver
Electron Isolation
Jet/Summary
UK CMS:
Bristol
Global
Trigger
Processor
GT
TPG
Calorimeter
Electronics
Interface
CMS:
Vienna
Muon Global Trigger
Iso Mu MinIon Tag
CMS ECAL:
Lisbon/
Palaiseau
72 φ x 60 η H/ECAL
Towers (.087φ x
.087η for η < 2.2 &
.174-195η, η > 2.2)
FCAL:2x(12 φ x 12 η)
MinIon Tag for
each 4φ x 4η region

Calorimeter Geometry



η = 3.0 → 5.0 :



2 CMS HF Calorimeters mapping onto Trigger System Jet/Summary Card

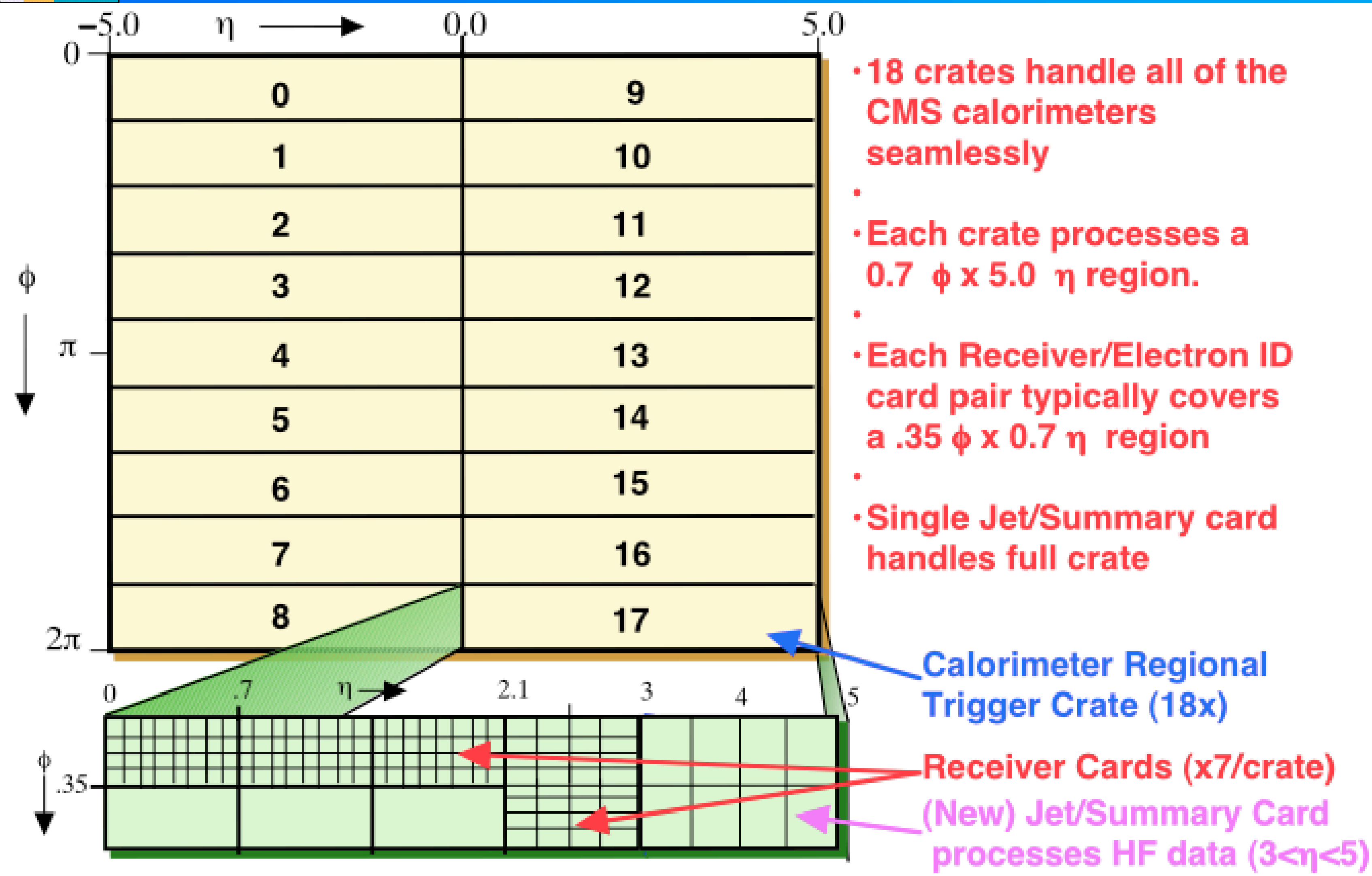
Readout segmentation: 36φ × 12η × 2z × 2F/B

Trigger Tower segmentation: 18φ × 4η × 2F/B

EB, EE, HB, HE map to 18 RCT crates

Provide e/□ and jet, □ E_T triggers

Trigger Mapping



- 18 crates handle all of the CMS calorimeters seamlessly
- Each crate processes a 0.7 ϕ x 5.0 η region.
- Each Receiver/Electron ID card pair typically covers a .35 ϕ x 0.7 η region
- Single Jet/Summary card handles full crate

Electron/Photon Algorithm

Trigger Primitive Generator

Fine grain — Flag Max of (, , ,) & Sum ET

Regional Calorimeter Trigger

E_T cut — + Max ( ) > Threshold

AND

Longitudinal cut (H/E) — / < 0.05

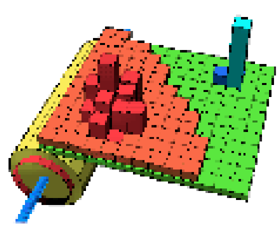
AND

Isolation, Hadronic & EM — < 2 GeV

AND

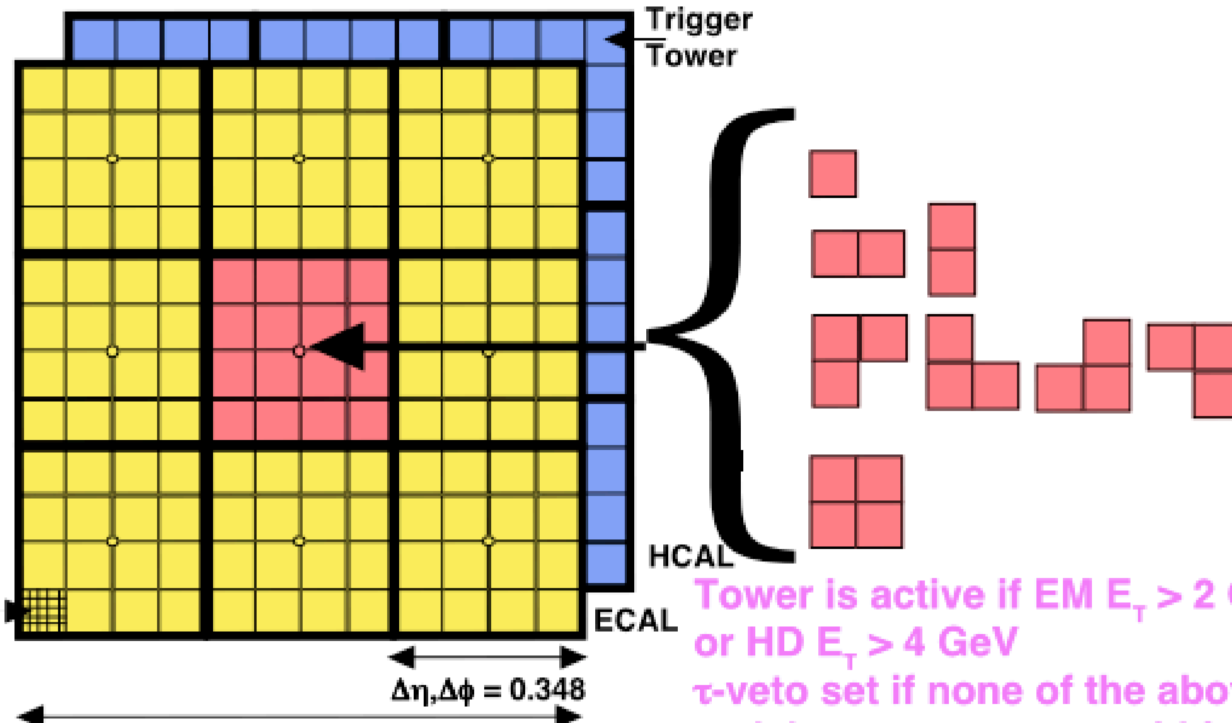
One of (, , ,) < 1 GeV

ELECTRON or PHOTON



□/ Jet Algorithm

Input from E/HCAL:
Programmable 8-bit
non-linear scale
Converted to linear scale
and summed to obtain
10-bit range jet/τ E_T



Tower is active if EM $E_T > 2$ GeV
or HD $E_T > 4$ GeV
τ-veto set if none of the above
activity patterns seen within 4x4

Jet or τ E_T

- 12x12 trigger tower E_T sums in 4x4 region steps with central region > others
- Larger trigger towers in HF but ~ same jet region size, 1.5 η x 1.0 ϕ

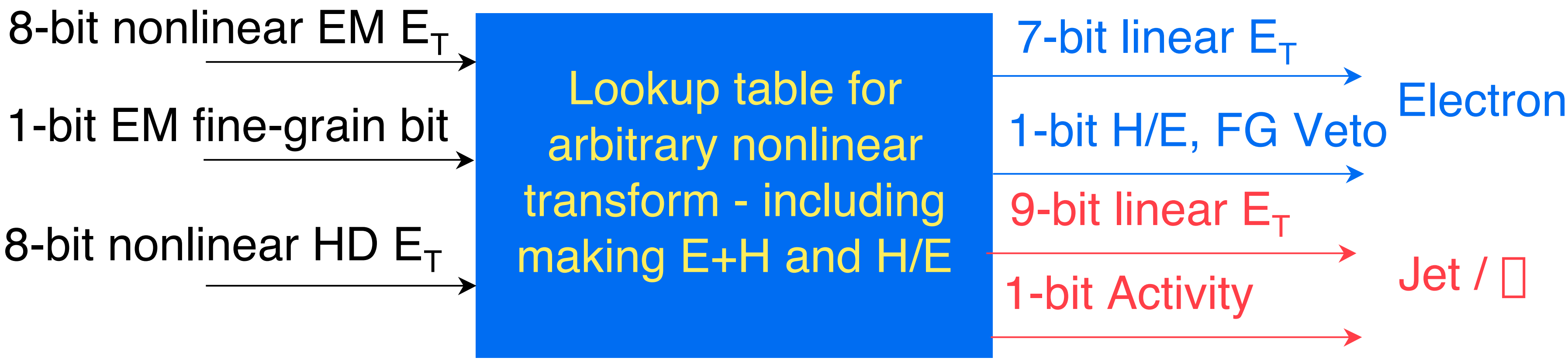
τ algorithm (isolated narrow energy deposits), within $-2.5 < \eta < 2.5$

- Redefine jet as τ jet if none of the nine 4x4 region τ-veto bits are on

Output

- Top 4 τ-jets and top 4 jets in central rapidity, and top 4 jets in forward rapidity

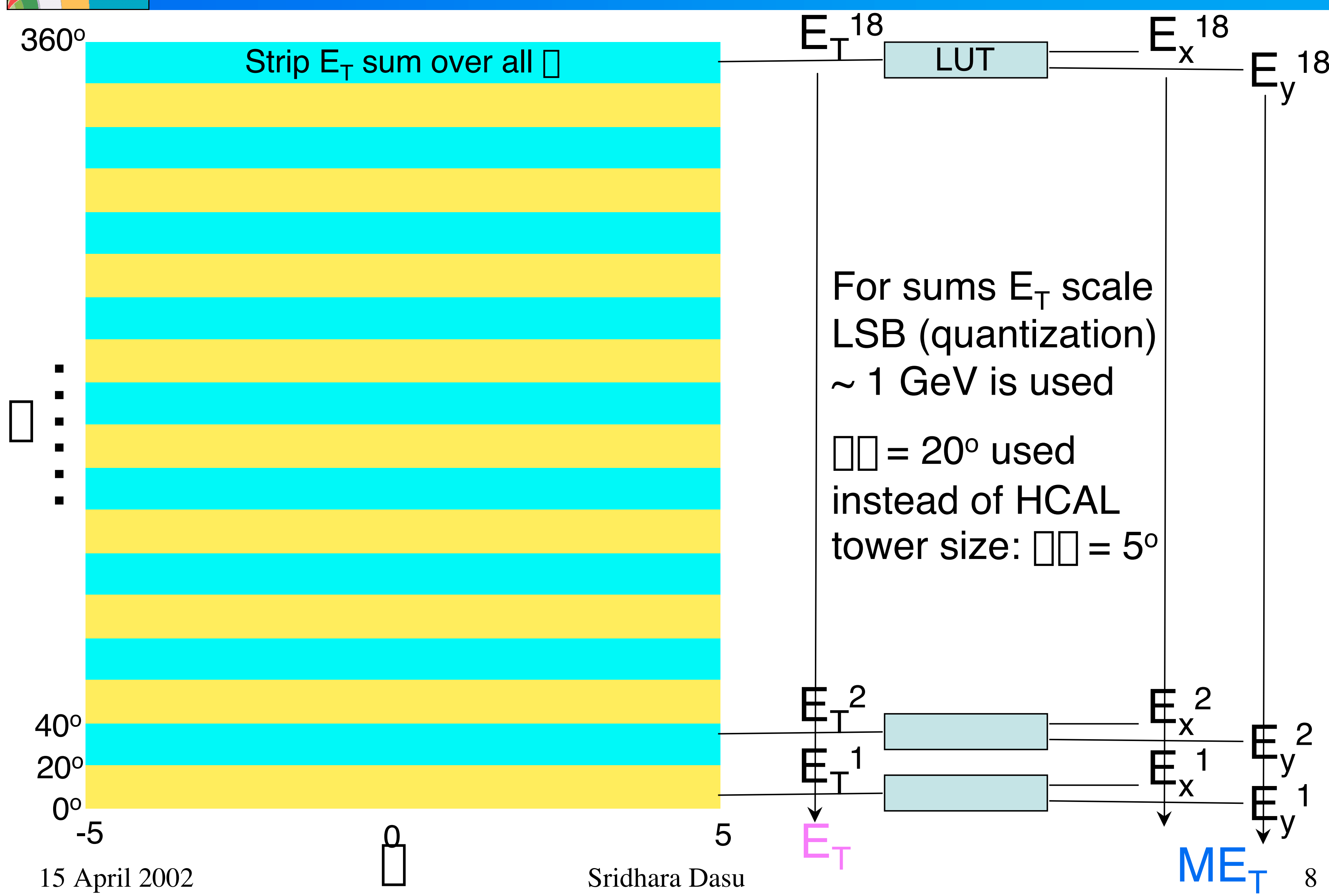
Tower Level Memory LUT



Fully programmable LUT, Current default values:

- **Electron scale: 0.5 GeV LSB, E^{max}=63.5 GeV**
- **Veto: OR of fine-grain veto and H / E < 5%**
- **Jet / τ scale (E+H): 1.0 GeV LSB, E^{max}=511 GeV**
  - **Jet energy (12x12 tower sum), E^{max}=1 TeV**
- **Activity level for τ pattern: E > 2 GeV, H > 4 GeV**

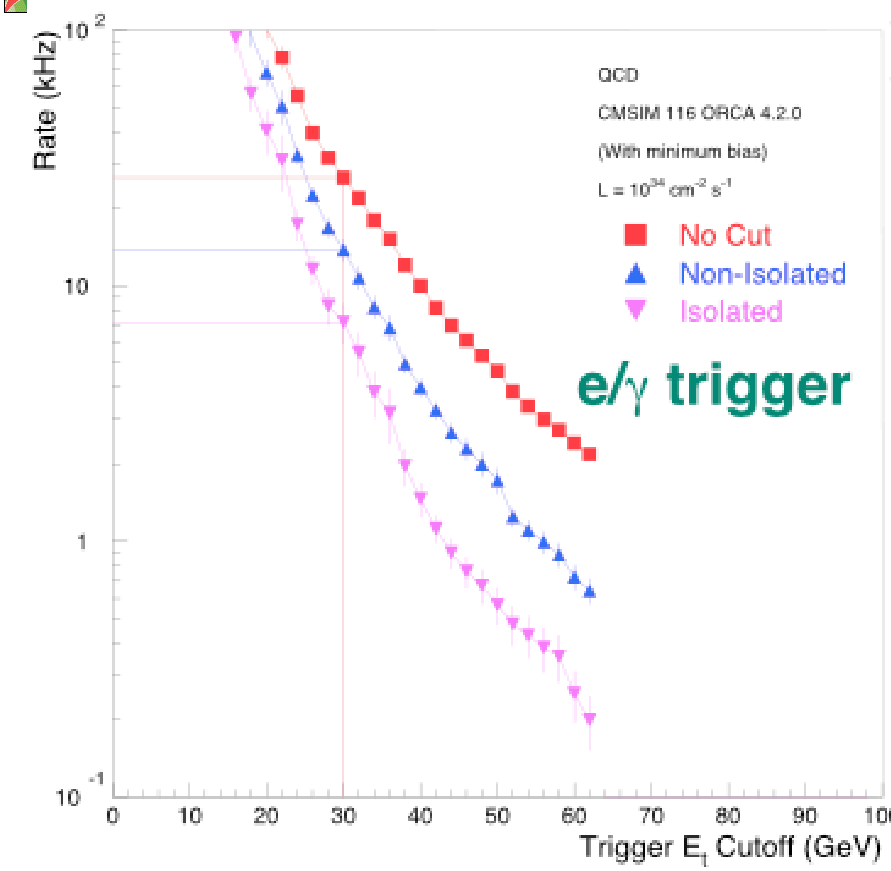
Missing / Total E_T Algorithm

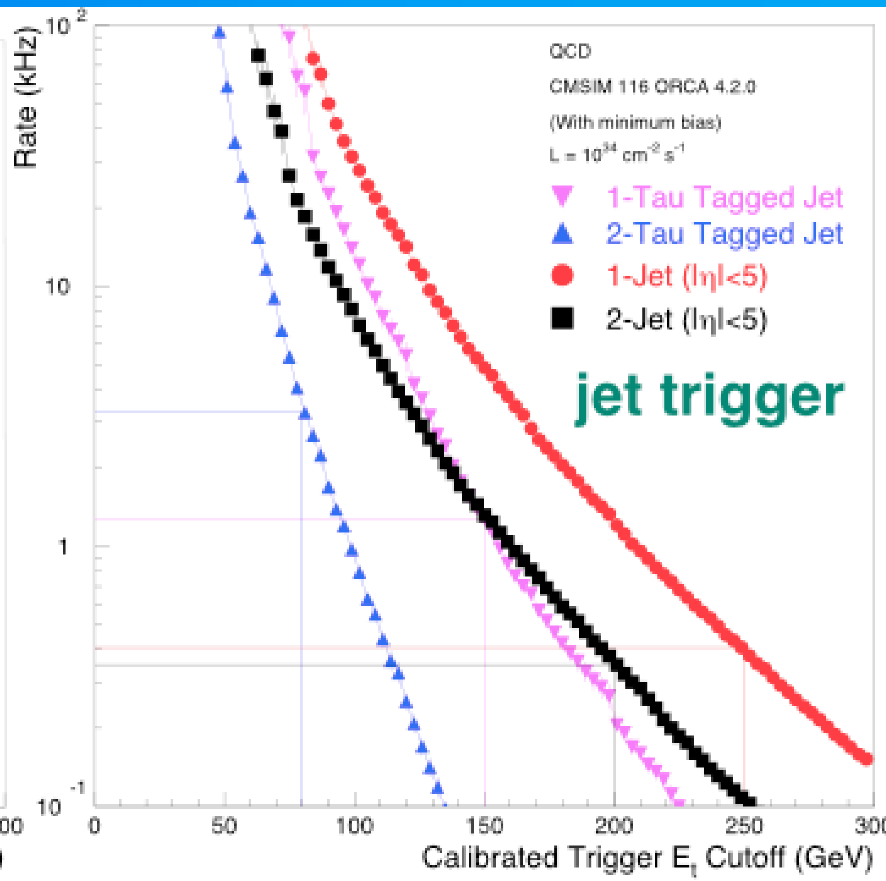


For sums E_T scale LSB (quantization) ~ 1 GeV is used

$\Delta\phi$ = 20° used instead of HCAL tower size: $\Delta\phi$ = 5°

Trigger Rates Vs Threshold

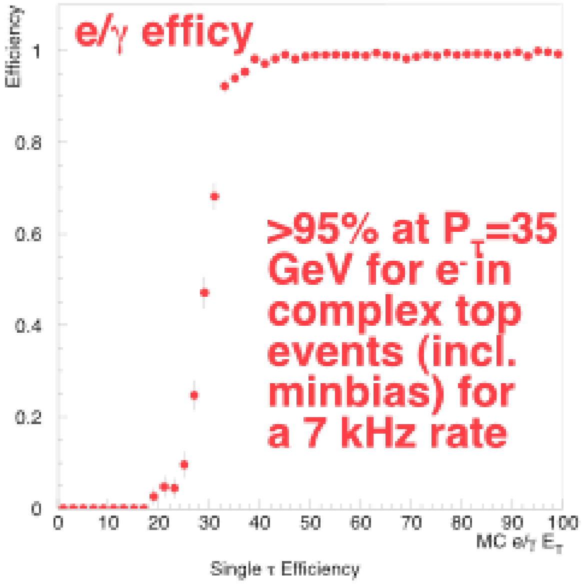


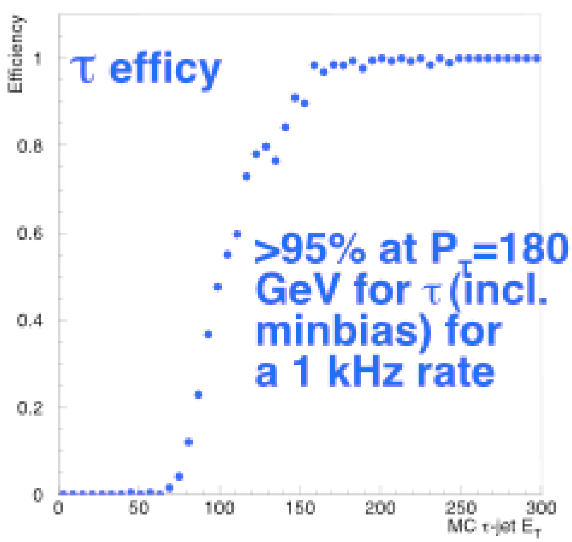


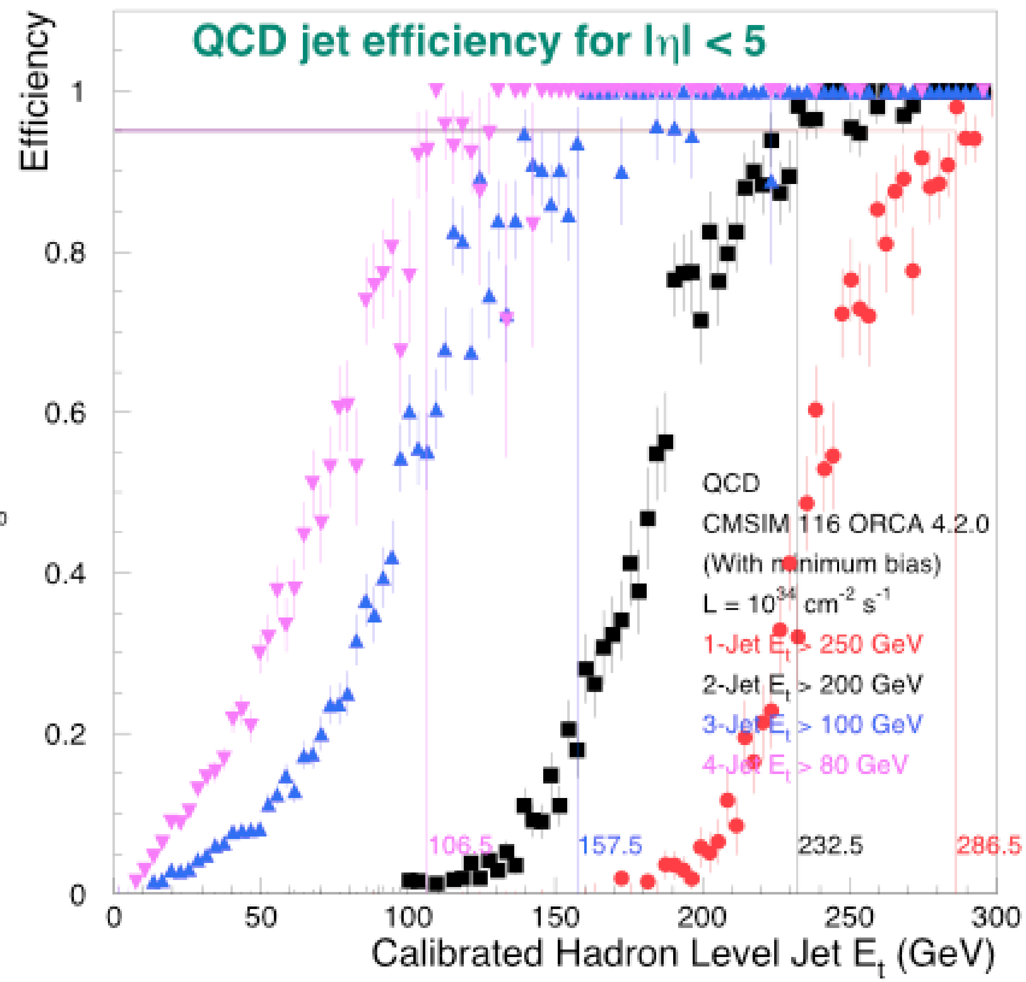
Rates drop sharply with trigger E_T cutoff

- Provides ability to tune cuts to sustain rates during operation
- For electron several cuts are available to optimize efficiency versus rate
- For all trigger types there are tunable parameters, e.g., look-up-tables
- QCD background rates are within target (~12 kHz for calorimeter triggers).

Trigger Efficiency Turn-on







>95% at P_T=286, 232, 157, 106 GeV for individual 1,2,3,4 jet triggers (incl. minbias) (~0.5 kHz rate each totalling ~2 kHz)

Cal Trigger Rates: 2 x 10^{33} cm^{-2} s^{-1}

Trigger	Threshold (GeV)	95% Eff. (GeV)	Individual Rate (kHz)	Cumulative Rate (kHz)
e	20	27	4.9	4.9
ee	15	19	0.2	5.0
□	89	~114	3.8	8.6
□□	75	~100	0.7	8.8
j	130	152	1.5	9.5
jj	115	131	0.8	9.5
jjj	75	77	0.3	9.6
jjjj	55	62	0.2	9.6
e·j	10&100	15&125	0.4	9.8
e·□	10&75	15&~100	0.8	10.0
Missing E_T	140	200	0.01	10.0
e·ME_T	10&75	15&140	0.4	10.3
j·ME_T	60&90	80&150	0.7	10.6
Total E_T	600	1200	0.04	10.6
H_T	400	470	0.6	10.7
e(NI)	45	51	0.2	10.8
ee(NI)	25	37	0.03	10.8
Total Rate				10.8

Selected Scenario: 5 kHz e/g, 5 kHz □,jets, 1 kHz combined, rest □

Physics Efficiency: 2 x 10^{33} cm^{-2} s^{-1}

Scenario:

5 kHz e/□,

5 kHz □,jets,

1 kHz comb,

rest □

No generator level cuts other than requiring trigger objects within calo. (□<5) or tracker (e,□,□) acceptance

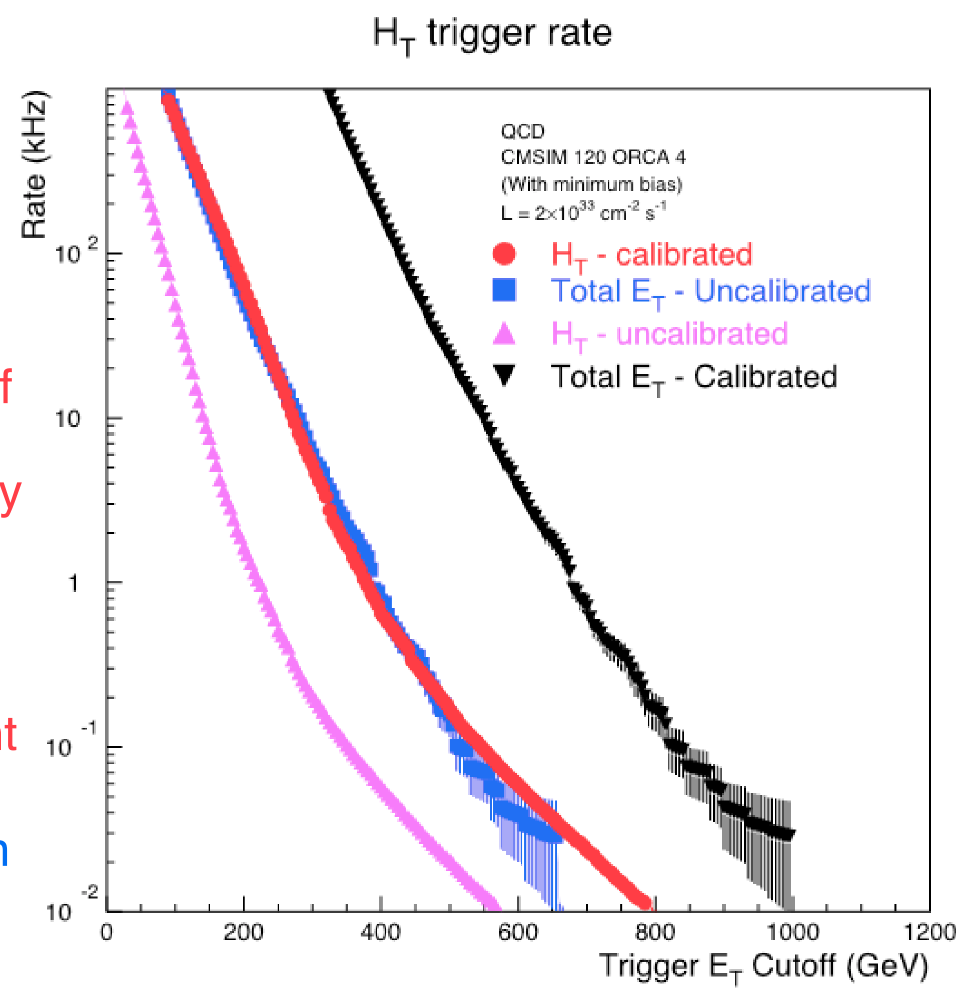
Channel	Total Efficiency	Trigger Efficiencies by trigger type (individual) cumulative				
W□ e□	70	e (70) 70				
t□ eX	91	e (82) 82	e·□ (62) 86	□ (55) 89	jjj (24) 90	e·j (54) 91
Z□ ee	94	e (93) 93	ee (76) 94			
H(115)□ □□	99	e (99) 99	ee (82) 99			
H(150) □ WW □ e□X	87	e (78) 78	e·□ (43) 81	□ (34) 83	e·j (39) 85	j (28) 87
H(135)□ □□□ ej	84	e (70) 70	e·□ (46) 79	e·j (46) 82	□ (38) 84	j (34) 84
Charged higgs (200 GeV)	98	□ (85) 85	j (77) 96	j·mE$_T$ (60) 98		
H(200)□ □□□ jj	81	□ (75) 75	□□ (50) 79	j (24) 81	jj (9) 81	
H(500)□ □□□ jj	99	□ (94) 94	□□ (64) 94	j (94) 99	jj (73) 99	
t□ jets	53	H$_T$ (39) 39	jjjj (26) 43	jjj (26) 46	jj (21) 47	j (35) 53
mSUGRA	99	j (99) 99				
H(120) □ bb	41	jjj (12) 12	j (27) 30	□ (26) 41	jj (16) 41	
Invisible higgs (120 GeV)	44	j·mE$_T$ (39) 39	j (22) 41	□ (13) 44		

Good Jets

- L1CaloTrigger finds jets of three types
  - Central, Forward and □jets
    - We send GT 4 objects of each type
    - These are mutually exclusive lists
    - For pure jet triggers, we need to use objects from all three categories, i.e., combine and re-sort
    - Although, this is easy to implement in software, we will use too many GT algorithm slots
  - Use good jet (E_T>Threshold) counts
    - Can count within programmable □ cuts
      - Several counts available
      - For example: 2 jets in central, 1 in +forward, 1 in -forward
    - Need simulation studies to define what is useful

H_T Trigger

- Total scalar E_T integrates too much noise and is not easily calibrated
  - At L1 tower-by-tower E_T calibration is not available
- However, jet calibration is available as f(E_T, □, □)
- Therefore, H_T which is the sum of scalar E_T of all high E_T objects in the event is more useful for heavy particle discovery/study
  - SUSY sparticles
  - Top
- GCT should be able to implement it (FPGAs + flexible backplane)
  - Use top 8 or 12 candidates in sorted good jet list
  - Sum E_T of good jets with E_T>threshold (e.g., 10 GeV)



GCT/GT Algorithm Agreement

- H_T from GCT to GT on separate cable in same format as E_T
- Study jet counts with an eye towards increasing numbers and categories
  - Works on good* jets (E_T cut)
    - *Should include all 3 categories (C + F + □)
  - Decide by June CMS Trigger Meeting
- Jets are calibrated with LUTs
- Keep 4 x (C + F + □) = 12 Jet List to GT

Summary

- RCT preproduction prototypes implementing the algorithms and programmability as described in this talk are built
  - The default values for LUTs coded in ORCA perform quite well for discovery physics
  - Need to further optimize the use of L1 LUTs
- GCT will implement good jet counts with cuts on various □ and □ regions, and H_T trigger
  - Need to explore the use of the jet counts for use in multi-jet physics events
    - Will help save some GT algorithms
- Topological trigger cuts in GT
  - Jim Brooke started exploring □□ cut for WW fusion
- L1 group will be happy to help anyone interested in optimization of cuts to improve trigger performance.